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Sputtered Glass Waveguide for Integrated Optical Circuits

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A series of papers which appeared in the September 1969 issue of the Bell System Technical Journal treated the theory of dielectric waveguides and stressed the potential use of such media for optical communication circuits.[1-4] Here we report on the realization of low-loss, thin glass films which can be used for circuit fabrication. Methods of preparing planar films and waveguides having rectangular cross section are described along with the techniques used in evaluating their optical characteristics.

The films we used for waveguide fabrication have been prepared by RF Sputtering of suitable glasses. The sputtering system used was oil-diffusion pumped and had five-inch diameter electrodes. Oxygen was used as the sputtering gas. The best films obtained to date were made by sputtering Corning 7059 glass. For convenience, in the early stages of this work, laboratory slides have been used as substrates. Necessary steps were taken to ensure that the substrates were clean.

The index of refraction of the films was measured to be 1.62 by determining Brewster's Angle for the films as described by Abeles.[5] From the color of the film and by interferometer methods the film thickness was found to be about 0.3 μm.

The transmission loss of the films was measured by two methods. Both use prisms to launch a light beam into the film.[6,7] In method 1 it is assumed that the scattering centers in the films are uniformly distributed. A fiber optic probe is then used to measure the intensity of the light scattered at right angles to the film. In method 2, the intensity of the output beam is measured as a function of launcher position along the film. Method 2 appears least accurate due to variations in launching efficiency as a function of prism movement. Method 1 works well to losses of the order of 1 db per cm. Below this level, the variability in the strength of the scattering centers makes reliable measurements difficult. An increase in film length would partially overcome the difficulty of measuring low level scattering from random centers.

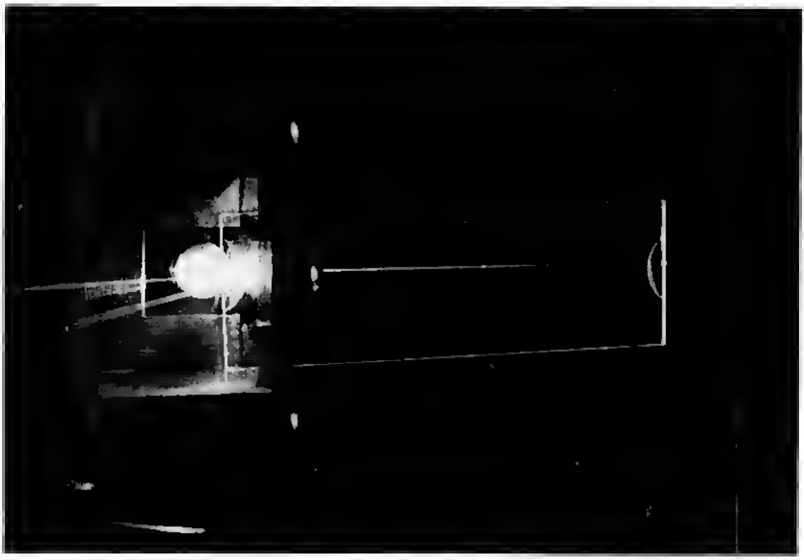

Fig. 1 — Light scattered from a beam propagating in a Corning 7059 glass film.

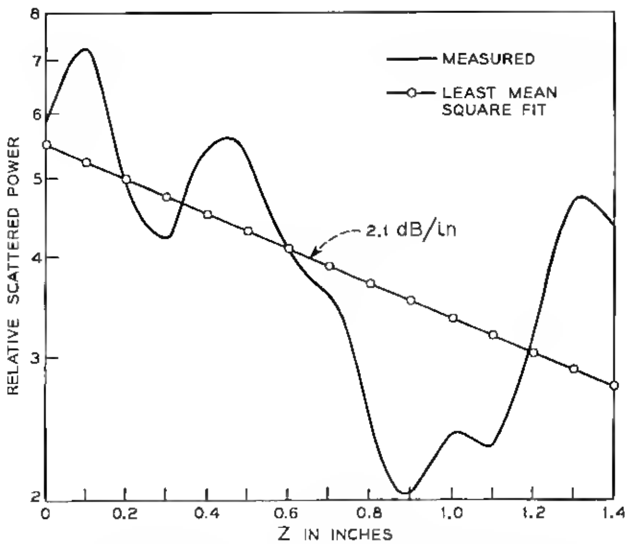

Fig. 2 — Relative scattered power versus length (7059 glass film).

Fig. 3 — Section of a rectangular waveguide (×1000).

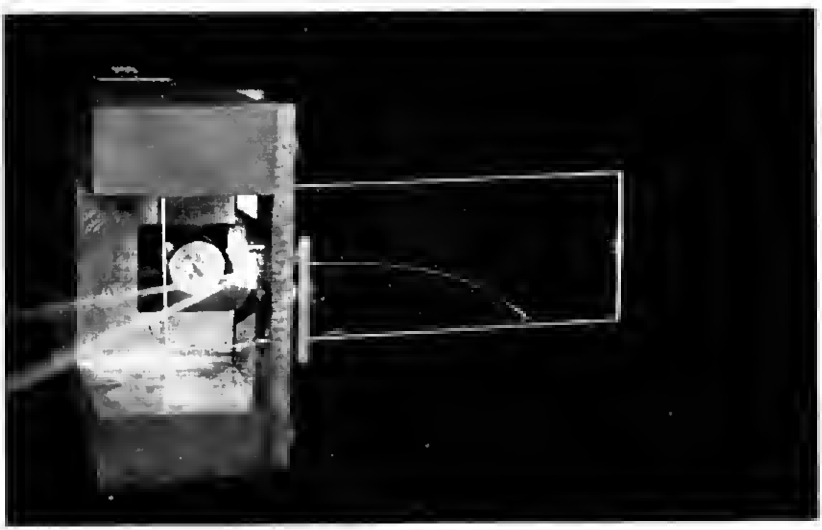

Fig. 4 — Light propagating in a curved section of rectangular waveguide.

Figure 1 is a picture of the light scattered from a beam propagating in the film. The intensity of scattered light as measured by the fiber optic probe is plotted in Figure 2. The average slope is less than -1 dB/cm. This result is in agreement with measurements made by the second method. The lack of uniformity of the scattered light intensity is due, at least in part, to inhomogeneities in the substrate. By using a higher quality substrate this source of scatter can be eliminated.

Curved sections of rectangular waveguides have been constructed from 7059 glass films by back-sputtering using quartz fibers as shadow masks. The waveguides were about 0.3 μm thick, 20 μm wide, and had a radius of curvature of about $\frac{1}{2}$ inch. A photograph of a typical section is shown in Figure 3. Figure 4 shows prism-launched light propagating in such a waveguide. Due to the small size of the waveguide our instrumentation will have to be improved before loss measurements can be made.

Our initial efforts have demonstrated the feasibility of using sputtered glass films and sputter etching in the fabrication of optical waveguides. This approach shows promise as a method of producing low-loss optical integrated circuits.

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